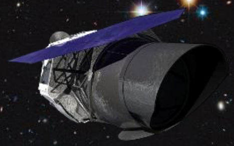
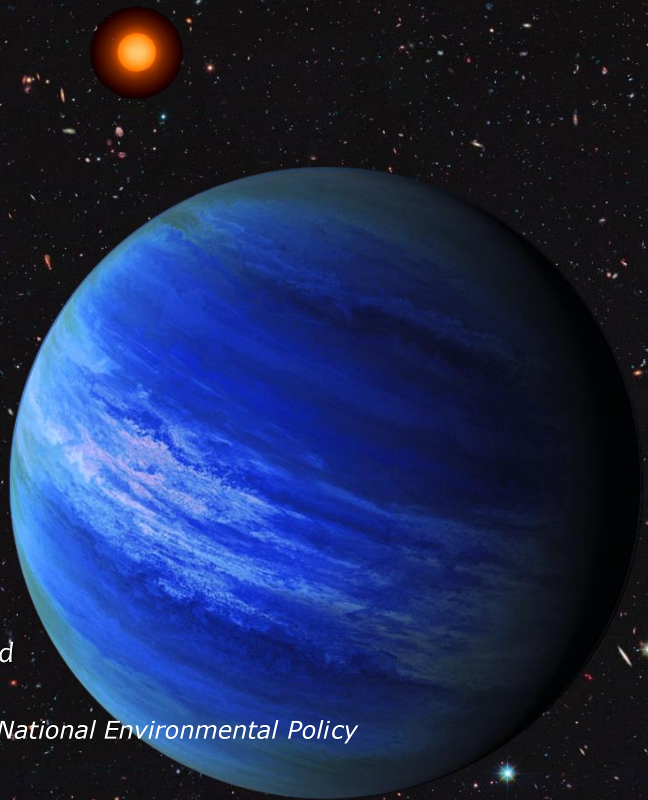
[redacted]



The WFIRST Coronagraph Instrument: a major step in the exploration of Sun-like planetary systems via direct imaging



Bertrand Mennesson

CGI Deputy Instrument Scientist

Austin SPIE Meeting, 15 June 2018

Jet Propulsion Laboratory
California Institute of Technology

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ASTROPHYSICS • DARK ENERGY • EXOPLANETS

Outline

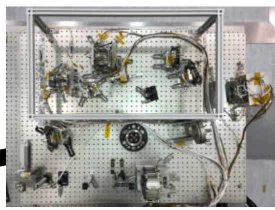
- CGI: a tech demo for future mission concepts (slides 3-4)

- Science capabilities enabled (slides 5-6)
  - 5 Main Exoplanet Science Themes
  - Example: Exozodi Observations

- Participating Scientist Program (PSP, slides 7-8)

CGI Tech Demonstrations Along the Beam Path

Autonomous Ultra-Precise Wavefront Sensing & Control System

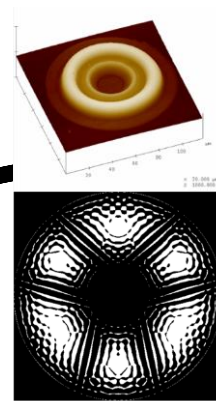


E. Cady & O. Alvarez-Salazar

First Use of Deformable Mirrors in Space

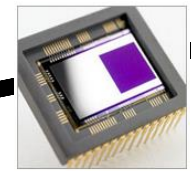
C. Lindensmith

High Contrast Coronagraph Masks



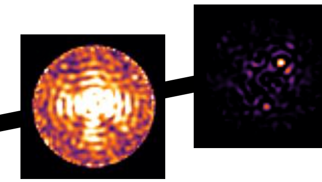
A.J. Riggs

Ultra-low Noise Photon Counting Visible Detectors



P. Morrissey & T. Groff

Image Processing at Unprecedented Contrast Levels



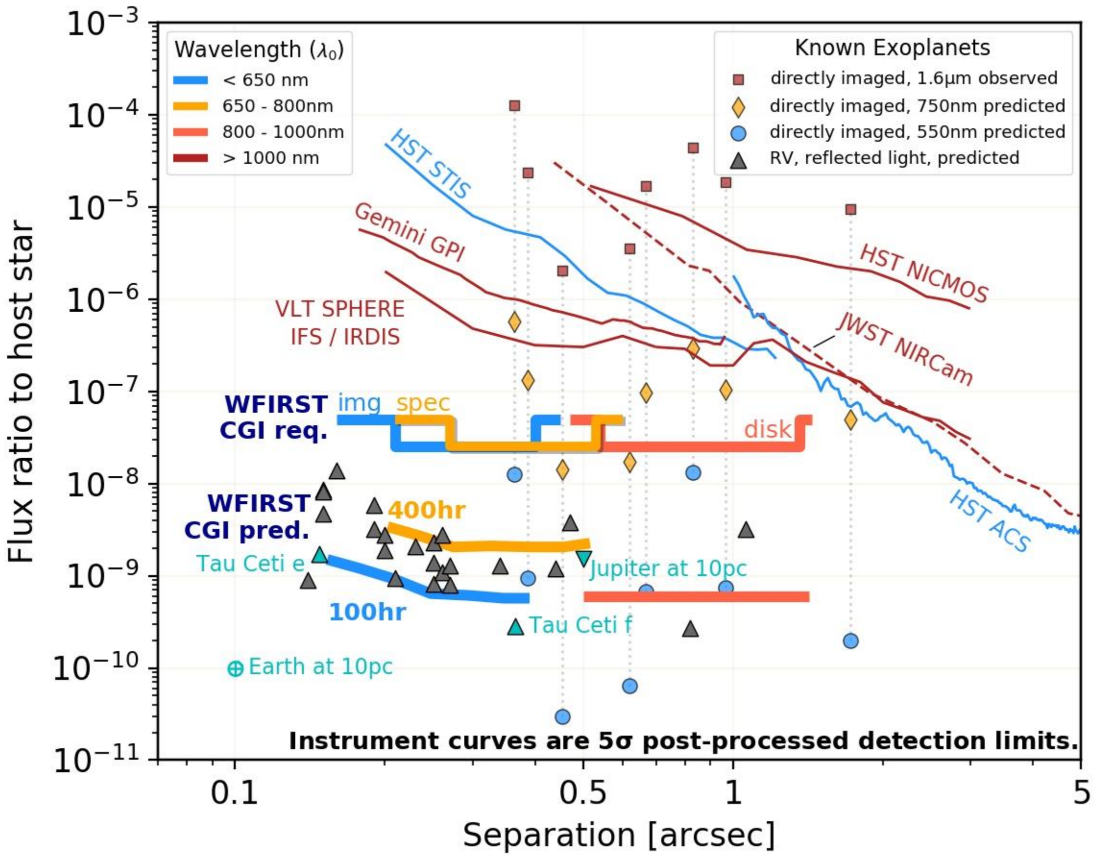
- **CGI will premiere in space many key technologies required for the characterization of rocky planets in the Habitable Zone (HZ), significantly reducing the risk and cost of future possible missions such as HabEx and LUVOIR**
- **CGI is a direct & necessary predecessor to these missions, and is a *crucial* step in the exploration of Sun-like planetary systems**

CGI in Context

- A successful CGI technology demonstration, i.e, meeting Level 1 BTRs 5, 6 & 7, will have science capabilities

- Exact science capabilities will depend on:
  - CGI Performance level demonstrated over BTRs
  - Time devoted to CGI observations

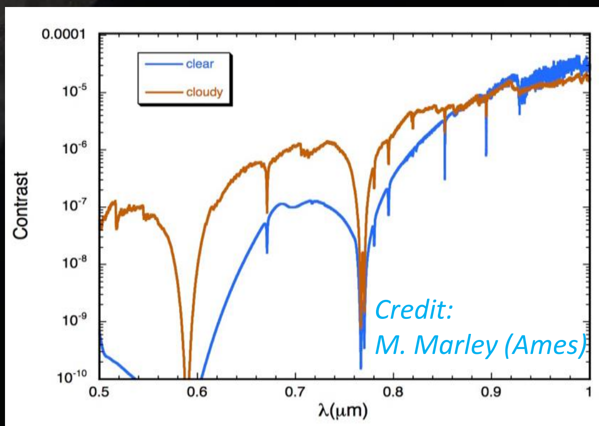
Credit: V. Bailey (JPL) et al.



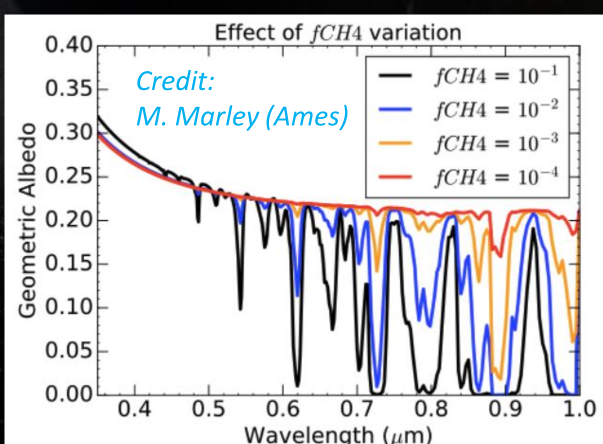
"RV" planets: planets already detected using the Radial Velocity technique and with minimum masses > 0.25 Jupiter mass

CGI Exoplanetary Science Themes

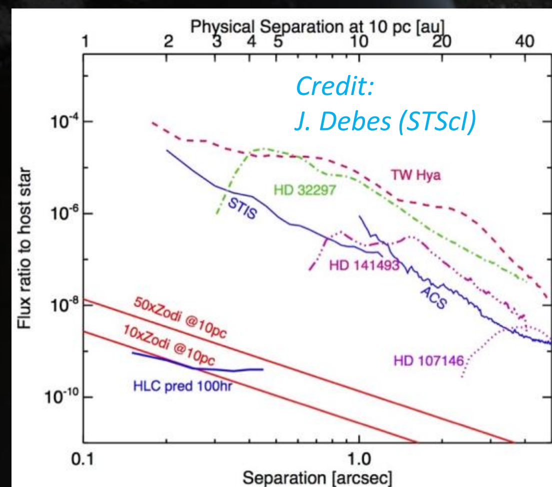
Self-luminous, young super Jupiters: atm. properties



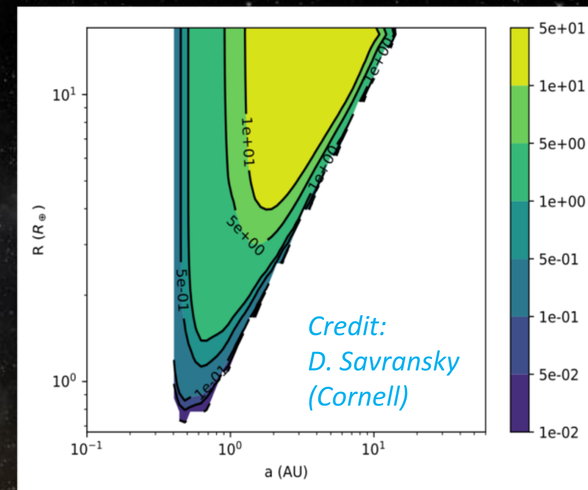
Mature Jupiter analogues in reflected light: mass & atm. properties



Circumstellar disks:
Protoplanetary (young)
Debris (mature)
Exozodi (mature, HZ)



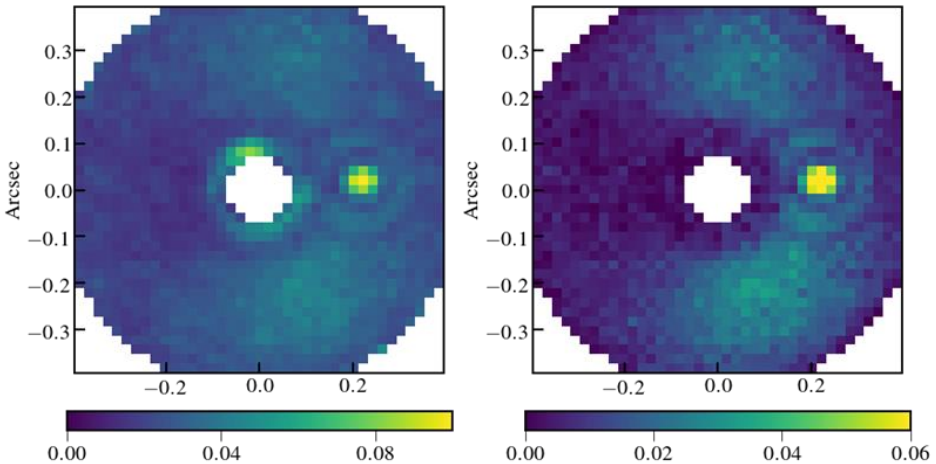
Possible blind searches for giant planets



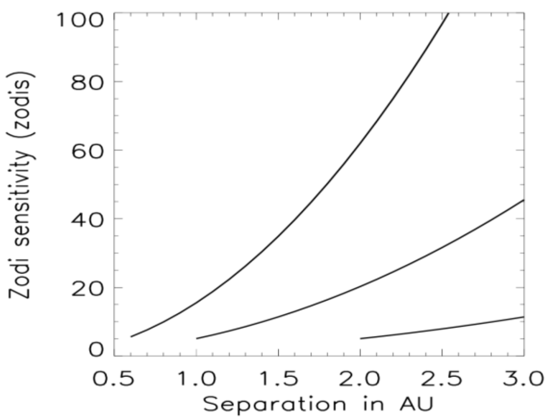
Possible characterization of HZ of nearby systems

Example: Exozodi

- CGI will cross an important threshold in debris disks physics
- CGI will obtain first *optical* images of faint exozodis → future missions
- Resolved images with "pixel" sizes of ~50 mas, mapping resonant dust structures
- Within the snow-line of sunlike stars within ~20 pc, and in the HZ of those closer than ~10 pc
- For solar type stars within 10 pc, sensitive to HZ exozodi emission levels of ~5x the solar density



1 Ori with 10 zodis and a hypothetical jovian planet at 1.6 AU
Figure credit: Rizzo, Zimmerman et al. 2018, GSFC

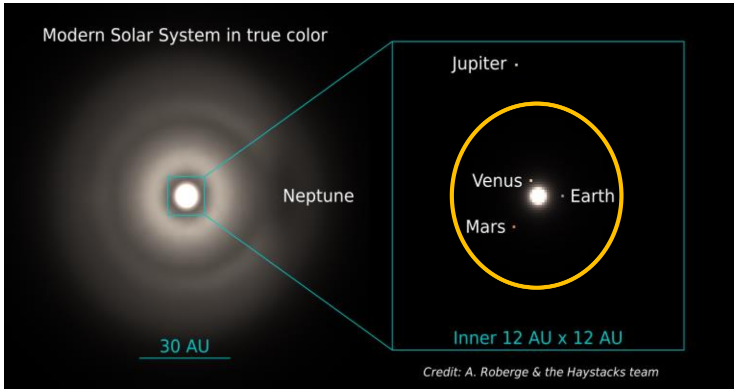


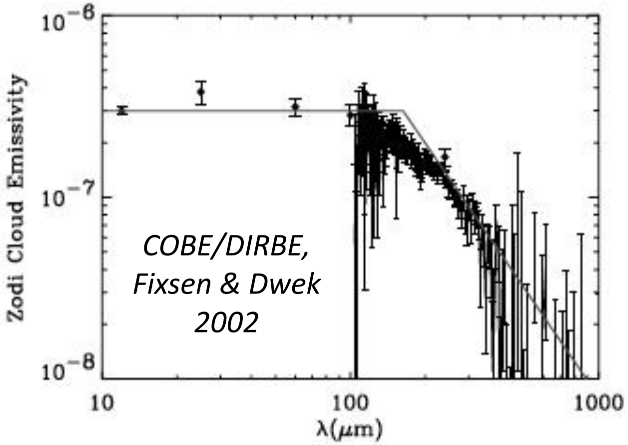
Zodi sensitivity vs separation for Solar type stars located at 4pc ,7pc and 14 pc, assuming 1/r^2 optical depth and CGI CBE performance

Credit: B. Mennesson (JPL)

Solar System Zodiacal Light (1 "Zodi")

- Warm circum-solar dust located within the asteroid belt, from <0.1 AU to ~3.3 AU



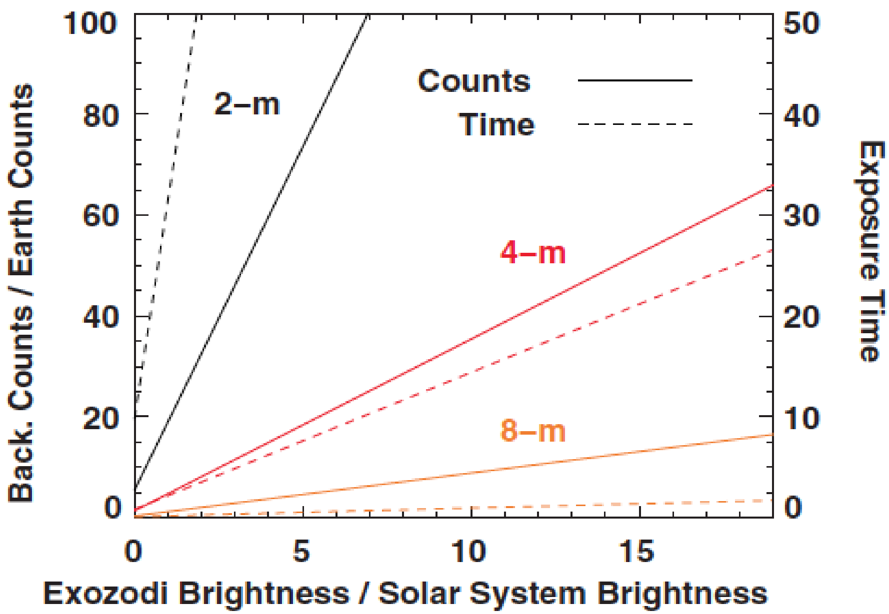


- Optically thin cloud of small (1–100 μm) dust grains created from asteroid collisions, comets evaporation and disruption
- Temperature and density profiles measured by COBE/DIRBE (Kelsall et al. 1998):
  - Tdust ~ 286 K $(r/1AU)^{-0.467}$; Optical depth ~ 10^{-7} $(r/1AU)^{-1.34}$
- Total mass equivalent to asteroid of 15km radius, or a few 10^{-9} Earth mass
- But total flux >100 times the Earth at both visible and mid-infrared wavelengths

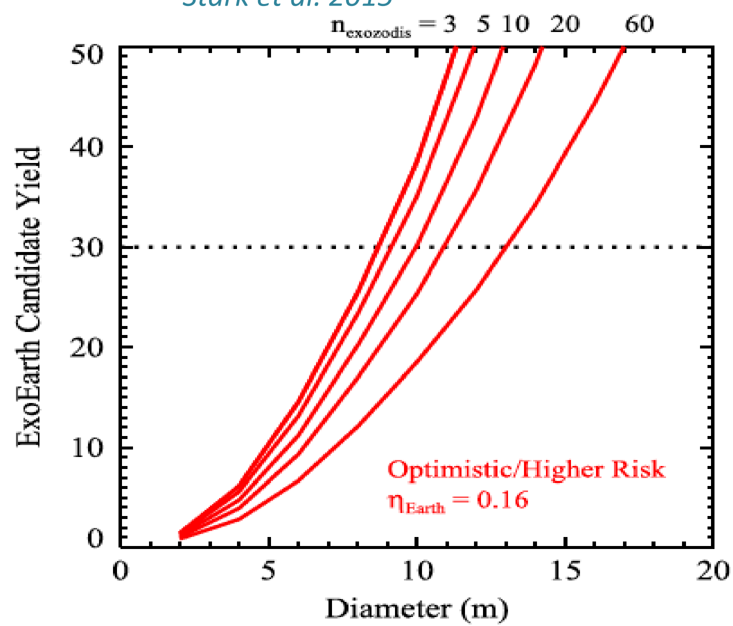
Why Do We Care So Much About Exozodis? (1/2)

- Disk-planet interactions and resulting structures in the habitable zone (HZ) of other stars have never been observed at low dust density levels (<100 zodis)
- Bright exozodiacal dust clouds are an impediment to the detection of faint rocky exoplanets in the HZ:
  - Sensitivity loss due to increased background noise:

Roberge et al. 2015



Stark et al. 2015



- For a 4m telescope viewing a solar system twin at 10 pc under 60 deg inclination, the exozodi counts per spatial element are 4x greater than the Earth seen at quadrature.
- F_{ez}/F_{earth} goes as (star distance / telescope diameter)^2 and increases with wavelength.

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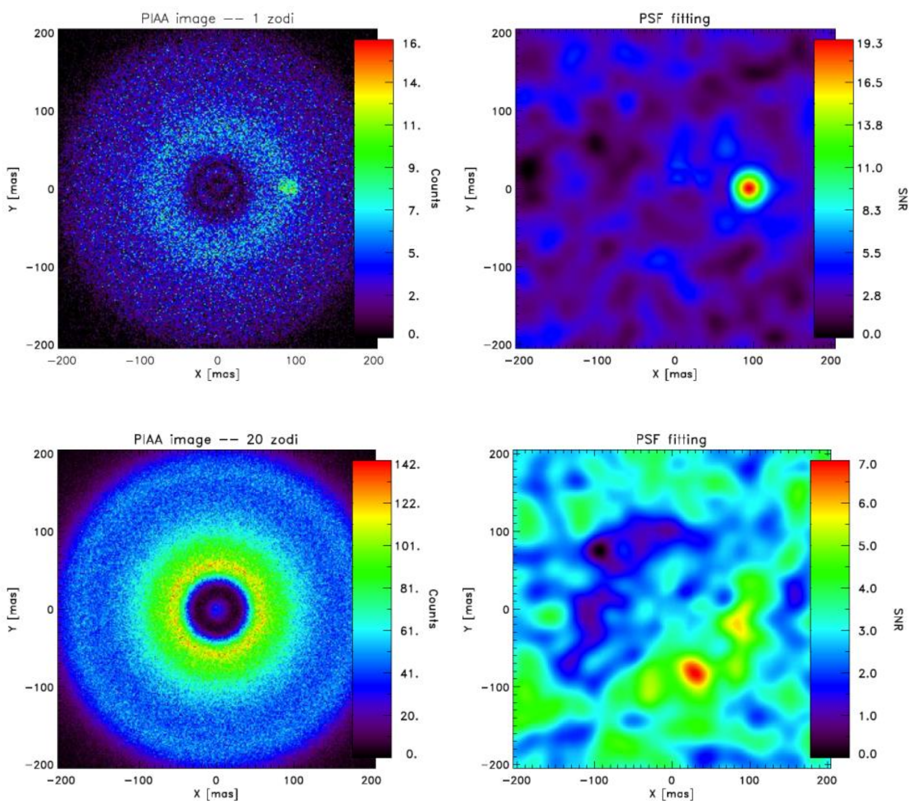
  - At ~x10 to x20 the solar level, resonant dust structures (analogous to the bright dust clumps trailing and leading the Earth in its orbit) will be significant sources of confusion:

1 "zodi"

20 "zodis"



Defrere et al. 2012:
Simulations of V-band coronagraphic observations with a 4m telescope

Back-up slides

Participating Scientists Program (PSP)

Notional PSP Program, to be confirmed by HQ and project in Phase B

- Core PSP members selected via peer review well before launch
- Makeup of PSP informed by CGI team needs
- PSP fully partners with CGI team during ‘tech demo’ phase (first 1.5 years of mission)
- If warranted*, years 1.5-2.5 could have more CGI time dedicated to science targets selected by PSP team
- If warranted*, years 2.5-5 could have an augmented (with further community selection) PSP or a full GO program

*warranted → CGI can do compelling science ; not currently budgeted

Why PSP?

- Mars Pathfinder was primarily a low cost **Tech Demo** lander
- Additional objectives - deploy and operate first rover on Mars and show functionality of 3 science instruments
- **Paved the way** for all future Mars landers and rovers
- **Without Sojourner we would not have had Spirit, Opportunity, Curiosity and upcoming M2020**

- Matthew Golombek, JPL PS for Pathfinder led a successful community NASA-selected PSP that yielded significant new science results
    - Determined the moment of inertia indicating Mars has a central metallic core
    - Rounded pebbles and cobbles suggest fluvial processes that imply liquid water in equilibrium with the atmosphere and thus a warmer and wetter past
    - Remote-sensing data correctly predicted a rocky plain safe for landing and roving with a variety of rocks deposited by catastrophic floods that are relatively dust-free